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14. ABSTRACT

We analyzed mixing and circulation measurements made in the Oregon Shelf upwelling system during the summers of 2000 and 2001. Three papers were written and submitted for publication. The overall thrust of the work has been to develop a variety of complementary techniques for characterizing internal waves and mixing rates using data from autonomous Lagrangian floats. These methods are rapidly maturing and are now able to provide long-term autonomous measurements of these quantities.

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Coastal Mixing

Final Performance Report

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LONG-TERM GOALS

We seek to understand the mechanisms of turbulence and mixing in shallow water sufficiently well to be able to specify useful parameterizations for coastal circulation models. We seek to understand the links between mixing rates, the circulation and productivity of the coastal ocean. We seek to develop the technology to make accurate Lagrangian measurement of ocean processes and the analysis techniques to use it.

OBJECTIVES

The short-term objective was to analyze mixing and circulation measurements made in the Oregon upwelling system during the summers of 2000 and 2001 and to publish papers.

APPROACH

Neutrally buoyant Lagrangian floats were deployed on the Oregon Shelf during the summers of 2000 and 2001. The float motion measures water parcel trajectories. High-frequency measurements along the float trajectory are used to infer mixing dynamics. Our primary task in FY07 was to publish completed analyses. This year completed this project.

WORK COMPLETED

Two papers were published. A third submitted. There is one more paper in the Oregon analysis series to be completed outside of this project.

- **D'Asaro, E. A., R.C. Lien, F. Henyey, 2007, High Frequency internal waves on the Oregon continental shelf**, ***JPO*****, 37,** 1956-1967**.** This paper describes the internal wave field on the Oregon shelf as measured by the floats. The energy levels are generally similar to open ocean except for additional tidal and high-frequency energy, the latter being mostly due to nonlinear internal waves. Energy levels vary geographically, being higher over rough topography. The nonlinear internal waves are not solitons and account for only a small fraction of the total energy.

- **D'Asaro, E. A., 2007, Convection and the seeding of the North Atlantic bloom, in press, *J. Marine Systems.*** This short paper results from the ONR supported Labrador Sea Convection Experiment. It is awaiting publication in a special issue of JMR on biophysical coupling. It uses a simple model to show how deep convection can maintain a population of plankton near the surface over the winter to seed the spring bloom. If plankton sink faster than the convective layer deepens, they will be lost and not be able to seed the bloom. The paper develops a number of new techniques for analyzing float data.

- C. **D'Asaro, E. A., 2007, A Diapycnal Mixing Budget on the Oregon Shelf, submitted, *Limnology and Oceanography*.** This manuscript, submitted to a special issue of L&O on autonomous and Lagrangian instrumentation addresses the relative roles of diapycnal and isopycnal mixing on the Oregon shelf using data from an isopycnal float. Using a new formulation of the diffusion equation in isopyncal coordinates and direct measurements of diapycnal diffusivity on the float, the validity of a purely diapycnal mixing balance is assessed. For temperature and salinity, diapycnal mixing is found to mostly predict the observed changes at the float, with some notable periods where isopycnal mixing must also be important. Thus both can be important at the measured scales of many meters and a few days. For chlorophyll, however, diapycnal mixing does not explain the observed variations. Instead, isopycnal mixing, planktonic sinking or possibly growth is important. The figure below shows the main results:

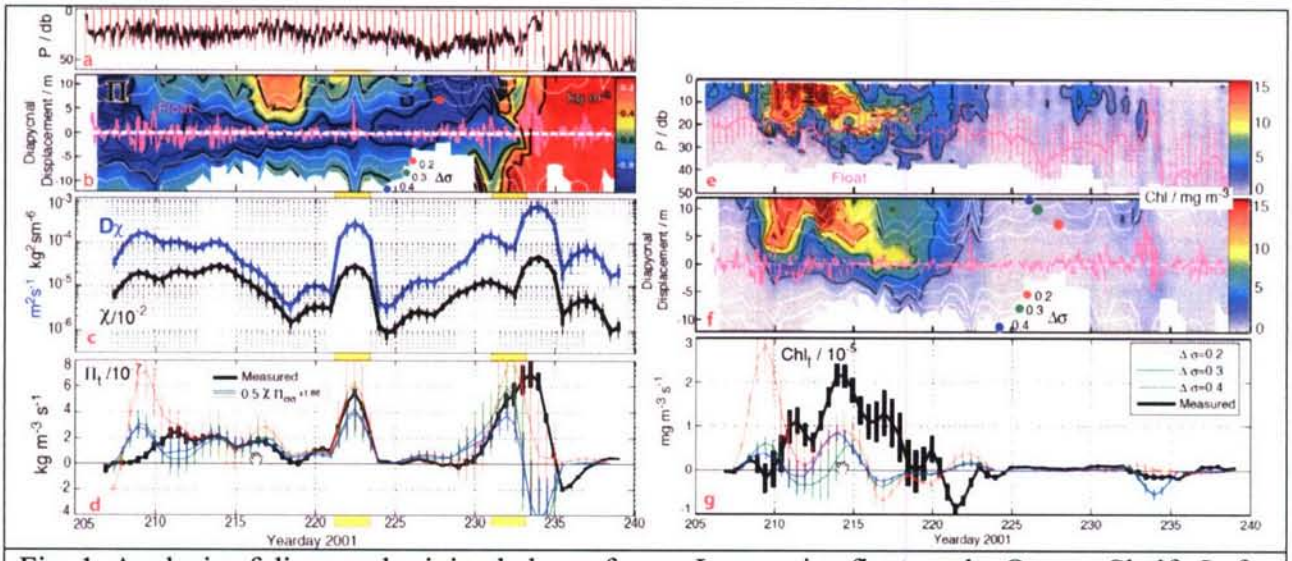

Fig. 1. Analysis of diapycnal mixing balance from a Lagrangian float on the Oregon Shelf. Left: for spice (a convenient combination of potential temperature and salinity). Right: for chlorophyll concentration. Panels: a. Float trajectory consisting of 9.8 hr long drifts near the 25.5 isopycnal (black) and profiles to the surface (red) every 12 hours. b. Spice contours relative to the isopycnal. Target isopycnal (white) is near a minimum in spice, i.e. in a layer of colder, fresher water. The analysis computes how fast diapycnal mixing will increase the spice by making it hotter and/or saltier. The float (magenta) moves only a few meters away from the target. c. Dissipation rate of potential density (χ, black) from high frequency float data and diapycnal

diffusivity (blue) computed from this. The diffusivity is highly variable ranging from 10x below typical open ocean values to 100x above. d. Comparison of the measured rate of change of spice (black) with that due only to diapycnal diffusivity (colored lines). The rate of change is almost always positive, but varies from near zero to $7x10^{-7}$ kg m^{-3} s^{-1}. Mostly the predicted and observed values agree well, showing that diapycnal mixing explains most of the observed changes. At times, most notably as the float penetrates a front near day 233, they do not, showing that isopycnal mixing is sometimes important. e. Chlorophyll concentration and averaged float depth (magnenta). f. Same in isopycnal coordinates. The time series is dominated by high chlorophyll concentrations, up to 15 mg m^{-3} just above the float with values at the float reaching only 7 mg m^{-3}. g. Comparison of measured rate of change of chlorophyll with that due only to diapycnal mixing. The two do not agree at all, showing that other processes control the chlorophyll distribution.

IMPACT/APPLICATIONS

The overall thrust of this work has been to develop a variety of complementary analysis techniques for characterizing internal waves and mixing rates using data from autonomous Lagrangian floats. These methods are rapidly maturing and are now able to provide long-term automous measurements of these quantities.

TRANSITIONS

None

RELATED PROJECTS

These floats are similar to those used in the CBLAST study of air-sea interaction in hurricanes, the NLIWI project in the South China Sea and the AESOP upper ocean boundary layer project.

PUBLICATIONS

D'Asaro, E. A., R.C. Lien, F. Henyey, 2007, High frequency internal waves on the Oregon continental shelf. *J. Phys. Oceanogr*, **37,** 1956-1967

D'Asaro, E. A., 2007, Convection and the seeding of the North Atlantic bloom, in press, *J. Marine Systems*

D'Asaro, E. A., 2007, A Diapycnal Mixing Budget on the Oregon Shelf, submitted, *Limnology and Oceanography*